Intermetallic Layers[1]

Solder bonds or “wets” to metals in a process which is joined by a metallurgical reaction with the base metal. This is a totally different mechanism than that which takes place when water wets a surface. This metallurgical bonding mechanism results in the formation of an intermetallic compound layer between the solder and the base metal. For example, if a molten Sn-based solder is placed in contact with clean Cu, the metallurgical reaction between Sn and Cu will result in the formation of a layer of **Cu_6Sn_5**. This intermetallic layer is the “glue” that holds the solder joint together. In normal soldering, the thickness of the intermetallic layer is on the order of 0.5 to 1.0 micrometer. It will rarely grow thicker than this in a liquid-solid reaction. However, solid-state metallurgical reactions can progress after solidification of the solder joint, especially at elevated temperatures. In the Sn-Cu system, a second intermetallic compound can form between the Cu and the Cu_6Sn_5 layer. This is **Cu_3Sn** which has quite different (non-solderable) properties than the Cu_6Sn_5 compound.

Intermetallic compounds have much different physical and mechanical properties than the metals which make them up. Typical intermetallics are very brittle and have poor electrical conductivity. In addition, if they are exposed to air, they will passivate (oxidize) very rapidly. Chemically, these passivated intermetallic surfaces are very stable and can not be reduced by the typical fluxes used in electronic soldering. Therefore, it is usually advisable to keep the layers as thin as possible, (generally between 1 and 2 micrometers) and protected from the atmosphere by a layer of solder. The reaction rate involved in intermetallic formation during solder wetting will vary considerably in different metal systems. For example, the Sn-Ni intermetallic formation rate is slower than the Sn-Cu formation rate, while the Sn-Ag formation rates are orders of magnitude faster. Stability of the different intermetallic compounds also varies between the metal systems.

Intermetallic compounds can be found in two places in a solder joint. Preferably, they are in a thin continuous layer between the solder filler metal and the base metals. Sometimes, intermetallic compounds can be found as particles, needles, or other forms within the solder matrix of the joint. This is not mechanically nor metallurgically desirable and the process conditions leading to such intermetallic inclusions should be avoided.

In surface mount technology (SMT) the majority of interconnections are made between active or passive components, (leaded or leadless) and Printed Wiring Boards (PWB). The PWB metallization is typically copper which has been solder coated. Therefore, the bond will actually be made between the solder and the copper. Leaded chip components will typically have Kovar or alloy 42 leads. Therefore, the bond will be between the solder and the nickel contained alloy, with the main intermetallics formed being Sn-Ni. In leadless parts, technology dictates that all silver metallization be coated with a barrier layer of nickel. Again, the solder bond will be between the Sn in the solder and the nickel barrier, forming Sn-Ni intermetallics. The process can literally use up one of the two metals making up the intermetallics. This process is commonly known as “leaching”. On a chip component, this can lead to exposed ceramic, or an underlying, non-solderable, refractory metallization. If solder coating is used up, this can lead to exposure of the intermetallic to the atmosphere, and non-solderability of the surface. This is the cause of “weak knees” in printed wiring boards.

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[1] DoD, "4.5.4," in *Mil-Hdbk-2000 (Cancelled)*, (4-Jul-90; reprint, US Navy, 1990), 17, 18.